# SECTION 6.0

# OUTSIDE PLANT METHODOLOGY

### 6.1 Overview

The loop module is designed to develop the loop costs associated with providing basic telephone service. BCPM 3.1 integrates more precise information regarding customer location than BCPM 1.1 with a customer location algorithm that establishes an optimal grid size based on an efficient network design.[28] Thus, the optimal grid size is determined by adhering to sound engineering practices that reflect forward looking, least cost technology for providing basic service. The "ultimate grid" is sized to comply with the technical requirements of a Carrier Serving Area (CSA). A CSA consists of a geographic area that can be served by a single digital loop carrier (DLC) site.

While BCPM 3.1 maintains some features of the loop engineering design in BCPM 1.1, the Model incorporates significant loop engineering changes to increase network efficiency. Recall that BCPM 1.1 squared the area encompassed by a CBG. For those CBGs with a density of less than 20 households per square mile, the squared CBG was reduced to a smaller square whose area is equivalent to the area encompassed within a 500 foot road buffer on each side of the roads within those low-density CBGs. BCPM 1.1 designed outside plant based on the assumption that customers are uniformly distributed throughout the road-reduced area.

BCPM 3.1 abandons the assumption in BCPM 1.1 that all customers are uniformly distributed throughout the CBG. BCPM 3.1's customer location algorithm uses housing and business line data at the Census Block (CB) level combined with information regarding the road network to more precisely locate customers. Utilizing all of this data, BCPM 3.1 models clusters of customers where they are indeed clustered and models sparsely populated areas where customers are, in fact, dispersed. This is all done while still retaining the shape and relative cable design of the wire center territory.

[28] See "Joint Comments of BellSouth Corporation, BellSouth Telecommunications Inc., U S WEST Inc., and Sprint Local Telephone Companies to Further Notice of Proposed Rulemaking Sections III.C.1", CC Docket 96-45 and CC Docket 97-160, filed Sept. 2, 1997.

Major changes to the BCPM 1.1 loop engineering include:

- directing main feeder toward population clusters, where appropriate;
- sharing of subfeeder, where appropriate;
- placing the DLC(s) at the road centroid of the grid;
- creating quadrants within the engineering area;
- running horizontal and vertical cables from the DLC site to each distribution area;
- placing the FDI at the road centroid of the quadrant where appropriate;
- allowing the road-reduced area to vary in size;
- permitting empty quadrants within grids, where appropriate;
- permitting sharing of the FDI between quadrants on either the left or right side;
- permitting co-location of the FDI with the DLC; and
- ensuring that the total cable length within a quadrant does not exceed the total road distance within that quadrant.

### 6.2 Engineering Standards

The engineering protocols most central to the design of this model include a maximum loop length for each CSA that is less than 12,000 feet. To ensure attainment of this standard, the maximum ultimate grid size is typically constrained to 1/25$^{th}$ of a degree latitude and longitude (approximately 12,000 feet by 14,000 feet). (Section 5.3.3 provides an in-depth discussion of BCPM 3.1's grid design.) The design of the ultimate grids ensures that the maximum copper loop length from the DLC site to the customer for any individual customer should not exceed 18,000 feet. A copper loop greater than 18,000 feet must be loaded or electronically extended at a substantial cost. The FCC clearly stated in its May 8, 1997 Order on Universal Service that no loaded loops are permitted.[29]

These constraints also ensure compliance with standard AT&T/Lucent and US LEC practices covering loop resistance and electrical (dB) loss.

[29] FCC Report and Order, "In the Matter of Federal-State Joint Board on Universal Service," CC Docket No. 96-45, Released May 8, 1997, Paragraph 250, criterion 1 of the FCC's 10 criteria.

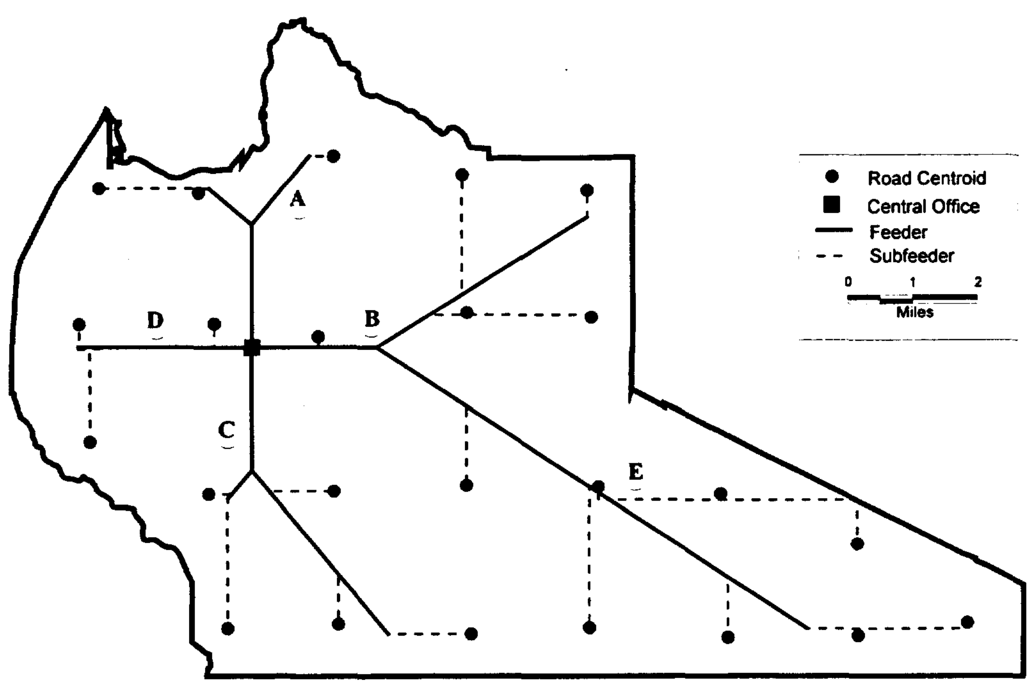
## 6.3 Feeder Design

The first step in designing the network is to create the feeder cable routes. This is done in the preprocessing portion of the modeling. Beginning at the wire center, a maximum of four main feeder[30] routes run directly east, directly north, directly west, and directly south from the wire center to serve four feeder quadrants. These routes run for 10,000 feet. This is based on the assumption that within 10,000 feet, customers are generally located within the perimeter of a town and that the town has some sort of gridded street complex. However, beyond 10,000 feet, the direction of each main feeder is determined by customer concentrations as reflected in the microgrid information data.

If the line count in the center 1/3 of a feeder quadrant is greater than 30% of the total feeder quadrant lines, this feeder remains a single feeder and potentially points to the population centroid of the entire feeder quadrant. The 30% figure is used to determine whether there is enough line demand in the middle to support the economics of a single feeder.

[30] There is a requirement for four main feeders. If due to the shape of the Wire center territory four feeders are not necessary, only the required number of feeders will be designed.

**Figure 6.1**
Feeder Plant
Glenville




If the line count in the center 1/3 of a feeder quadrant is less than 30% of the total feeder quadrant lines, the feeder splits into two main feeders, each potentially pointed at the population centroid in one half of the feeder quadrant. Each portion of the split main feeder is sized according to the number of customers that it serves. This modeling best depicts how a loop network is designed. This breakpoint should capture the need to split the cable to avoid any natural barriers. (An example of a split feeder is shown on the north directed main feeder (A), the east directed main feeder (B), and the south directed main feeder (C) in Figure 6.1). The length of the main feeder(s) is limited to the minimum distance necessary to reach the last subfeeder of an ultimate grid.

Anytime the model logic indicates that the main feeder should be redirected, or split, at the point 10,000 feet from the central office, a test is run to determine if the design produces the least cost network. Total feeder cable length (including feeder, subfeeder and sub feeder part two) for the redirected or split feeder system, potentially pointed to the population centroid, is compared with the total feeder cable length for a design where the main feeder is continued in the original cardinal direction, i.e. due north, south, east or west and subfeeders at right angles to the main. The design with the shortest total feeder cable length is selected.

### 6.4 Subfeeder Design

From the main feeder, subfeeders branch out toward the individual ultimate grids. Subfeeder is potentially shared by more than one ultimate grid. An example of this sharing is shown as area E in Figure 6.1.

Along a main feeder within 10,000 feet of the wire center, subfeeders may branch off the main feeder every 1/200$^{th}$ of a degree boundary.[31] For a single main feeder, i.e. a main feeder that does not split beyond 10,000 feet from the wire center, subfeeder branches upward or downward (vertically) from the main feeder in east and west feeder quadrants, and branches outward (horizontally) in north and south feeder quadrants. (See the west directed feeder (D) in Figure 6.1)

Along a main feeder beyond 10,000 feet of the wire center, subfeeder branches out at most, once between every 1/25th of a degree boundary. For a split main feeder that angles greater than 22 1/2 degrees from the direction of the original main feeder (away from the wire center), subfeeder emanates vertically upward or downward as appropriate, and horizontally outward away from the wire center, creating a fishbone pattern. For a split main feeder that angles less than 22 1/2 degrees from the original main feeder, subfeeder emanates outside of the subfeeder as explained above (away form the direction

[31] This corresponds to the boundaries of the underlying microgrids, i.e. the smallest grid size possible.

of the original main feeder cardinal line, i.e. due north, south, east or west) and emanates inside towards the cardinal line either horizontally for north and south directed main feeder or vertically for east and west directed main feeder. If the cardinal feeder line has extended from the 10,000 foot point, this interior subfeeder would create a right angle with the original cardinal line[32].

Subfeeder part 2 links subfeeder to the road centroid of an ultimate grid for those ultimate grids whose road centroid does not intersect the subfeeder. Thus, by definition, subfeeder part 2 is not shared by multiple ultimate grids.

A DLC site is established (where loop lengths exceed the copper/fiber breakpoint) within each CSA at the road centroid of the ultimate grid.[33] The number of DLCs placed at the DLC site depends on the number of lines served in that CSA.

If a CSA is served by copper feeder, the cross connect where copper feeder facilities are connected with copper distribution facilities (the feeder/distribution interface (FDI) site) is established at the road centroid for that ultimate grid.

Right and left connecting cables extend from the DLC location to the road centroid of each non-empty distribution quadrant. These connecting cables consist of horizontal connecting cables that extend east and west from the DLC site and vertical connecting cables that vertically connect the horizontal connecting cable to the road centroid of each of the non-empty distribution quadrants. Figure 6.2 shows an example of a grid distribution system with an empty quadrant.

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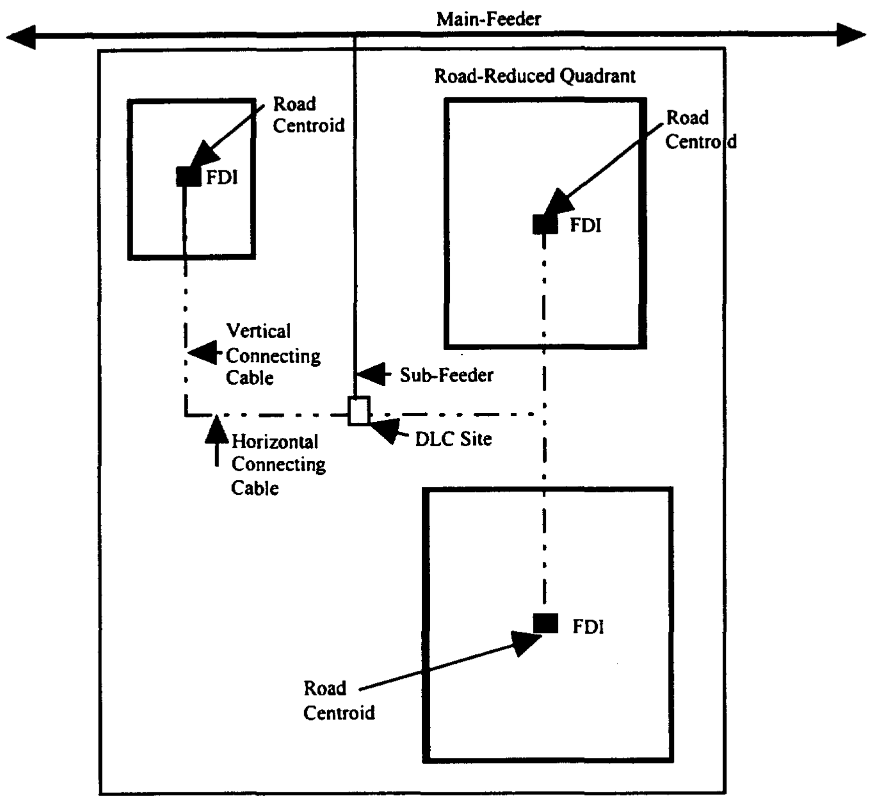
[32] In the case that both split feeders move at angles less that 22 1/2 degrees, the determination of which subfeeder serves grids that lie between the split feeders is made based on the shortest route to the road centroid of the grid.

[33] The road centroid is a point that represents the weighted average of the length of the roads within the defined area.

**Figure 6.2**
OUTSIDE PLANT DISTRIBUTION
Cabling to Quadrants




For purposes of summarizing plant investments, all cables connecting the DLC to remote FDIs are categorized as feeder, and any facilities that extend beyond the FDI to the customer are categorized as distribution plant.

### 6.5 Feeder Equipment

The Model allows for two DLC categories, each providing multiple size options of remote and central office terminal size. This permits placement of small DLCs in CSAs that serve a relatively small number of customers. Both large and small DLCs are assumed to be integrated DLC systems. In addition, the Model captures efficiencies garnered from large DLCs where appropriate. The decision to use either a small DLC or a large DLC is based on the number of lines the DLC can serve. Given an engineering fill factor of 90%, a small DLC is placed if the CSA serves less than 216 lines, i.e. 240 times 90%. This engineering fill factor is a user adjustable input.

A typical DLC remote cabinet size for a large DLC, such as the "Litespan-2000", can serve only up to 1,344 lines. BCPM places a second cabinet to complete a 2016 line system if applicable. Whether more DLCs are placed in that CSA depends on whether sound engineering practices call for another DLC or whether it is optimal to divide a grid further, into smaller ultimate grids, each representing a CSA. For example, it is possible for a single CSA to serve 5,000 customers if a large number of customers are located in a single office complex. In this case, multiple DLC cabinets/systems would be installed to provision the 5,000 lines.

### 6.6 Feeder Cable Requirements

The type of cable used in the feeder system is determined based on the specified copper/fiber breakpoint. The copper/fiber breakpoint is a user adjustable input.[34] The default input for the copper/fiber breakpoint is 12,000 feet. A copper/fiber breakpoint of 12,000 feet requires placing copper in the feeder if the maximum loop length from the wire center to all customers within an ultimate grid is less than 12,000 feet. If the loop length for any customer in the ultimate grid exceeds 12,000 feet, fiber is placed in the feeder to serve all customers in the ultimate grid. For all loops, cable beyond the DLC site is copper.

Feeder cables are sized to accommodate the number of working lines based on total residential, business, and special access lines. The size of feeder cables is based on the number of actual working lines adjusted by a variable engineering fill factor. For example, at an 85% engineering fill factor, a 400 pair cable can accommodate 340 working pairs before increasing the cable size. The default assumes a 75% engineering fill factor for the lowest density zone, an 80% engineering fill factor for the next two lowest density zones, and an 85% engineering fill factor for the remaining six density zones. These engineering fill factors for feeder cable are user adjustable inputs.

The required capacity for a segment of fiber feeder plant is determined in a similar manner. However, large DLC technology and small DLC technology cannot share fiber strands because of different transmission protocols. For large DLC systems, four fibers

[34] The Model allows the user to set the copper/fiber break point between 6,000 feet and 18,000 feet, given 3,000 foot increments.

can carry up to 2,016 voice grade paths. If the segment capacity exceeds this limit, four additional fibers are required for each increment of 2,016 voice grade paths. For small DLC systems, four fibers can carry up to 672 voice grade paths. Like large DLC systems, each additional increment of 672 voice grade paths capacity requires an additional four fibers. The voice grade paths are determined for each technology by summing the lines by Grid utilizing the particular technology and dividing the sum by the electronic fill factor.

The total capacity for a fiber feeder segment is the sum of the required large DLC fiber strands and required small DLC fiber strands. BCPM 3.1 determines the number of maximum size fiber cables and the size of the additional fiber cable to meet the capacity needs of the segment. The fiber feeder cable sizes available in the Model are 12, 18, 24, 36, 48, 60, 72, 96, 144, and 288 strands.

### 6.7 Distribution Plant Design

With the exception of the ultimate grids that remain microgrids in size, each ultimate grid, or equivalently, a CSA, is divided into four potential distribution quadrants.[35] The ultimate grid is quaded into four distribution quadrants at the road centroid of the ultimate grid which corresponds to the DLC site. Once the distribution quadrant is formed, data on the road network is used to determine the lengths of horizontal and vertical connecting cable and backbone and branch cable. For modeling purposes, a road-reduced area is developed as the area encompassed by a 500 foot buffer along each side of the livable roads (e.g., excluding limited access freeways and underpasses). While the road-reduced area is a simulation of reality, it is easy to conceptualize as a square centered about the road centroid of the distribution quadrant. The road-reduced area is equal to the area encompassed by a 500 foot buffer along each side of the roads within the distribution quadrant.[36] This is shown in Figure 5.5 in Section 5.3.4. No distribution facilities are placed within a distribution quadrant that

[35] Ultimate grids which are equivalent to a microgrid in size, are treated as a single distribution quadrant. This typically occurs in denser, urban areas.

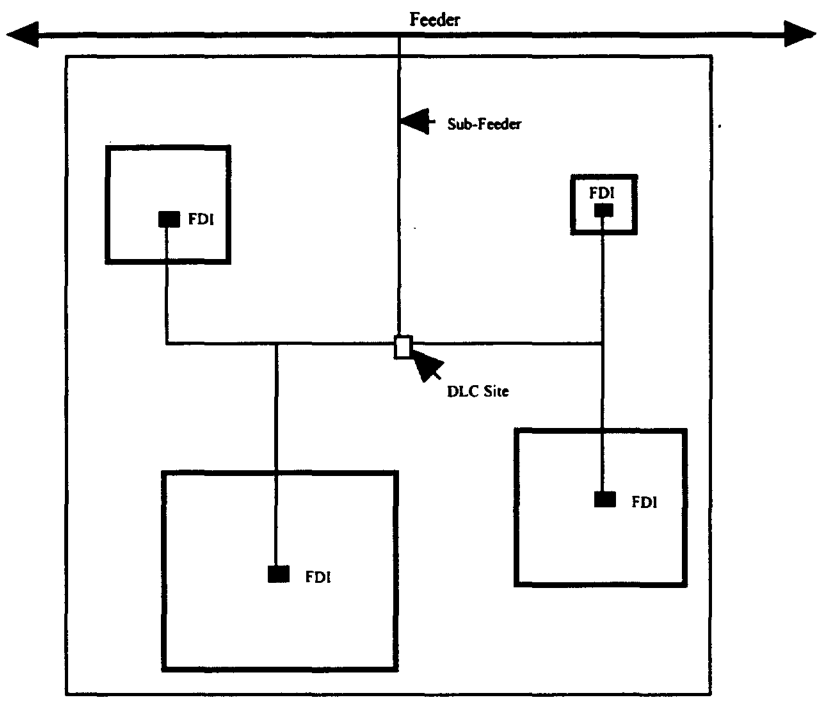
[36] In cases where an ultimate grid remains the size of a microgrid, a 500 foot buffer along the roads within a microgrid typically corresponds to an area that is greater than the area of the microgrid. In such cases, the area is not reduced in size. The Model constrains the road-reduced area so that it does not exceed the area of the microgrid.

does not have any roads, i.e. a non-populated distribution quadrant. The location of the centroid of the road-reduced area (with respect to the road centroid of the ultimate grid itself) determines the distance the horizontal and vertical connecting cables must traverse. The size of the road-reduced area and the number of customers in the distribution quadrant determines the length of the backbone and branch cable.[37] The road-reduced area is not used to locate customers, but as a modeling tool to determine likely cable distances required to serve customers in the distribution quadrant.

In determining the number of FDIs to install in an ultimate grid, the Model reviews the cable sizing used in the Grid. When the distribution cable sizing exceeds 1,200 pairs, the Model places an FDI at the road centroid within each populated distribution quadrant. Thus, the FDI is placed at the center of the road-reduced area. This is shown in Figure 6.3.

[37] The backbone cable is not tapered so as to have the capability to serve areas outside of the stylized square road-reduced area.

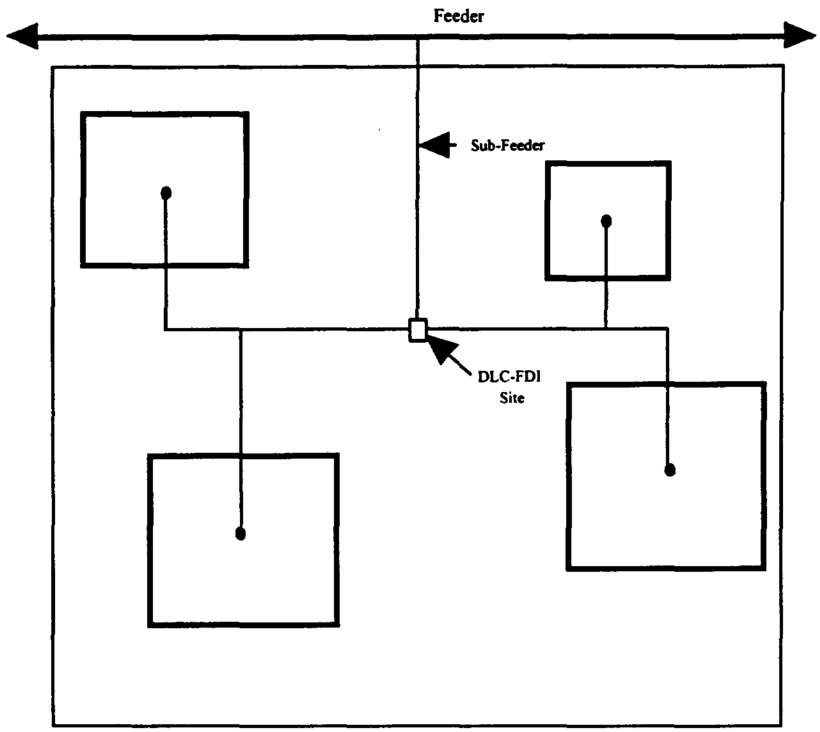
**Figure 6.3**
OUTSIDE PLANT DISTRIBUTION
**FDI Located in each Non-Empty Quadrant**
**(Total Lines > 1200)**




If there are no roads, and therefore, no population located within a particular distribution quadrant, no distribution plant is placed in that distribution quadrant. Horizontal and vertical connecting cable links the DLC to the FDI within non-empty quadrants.

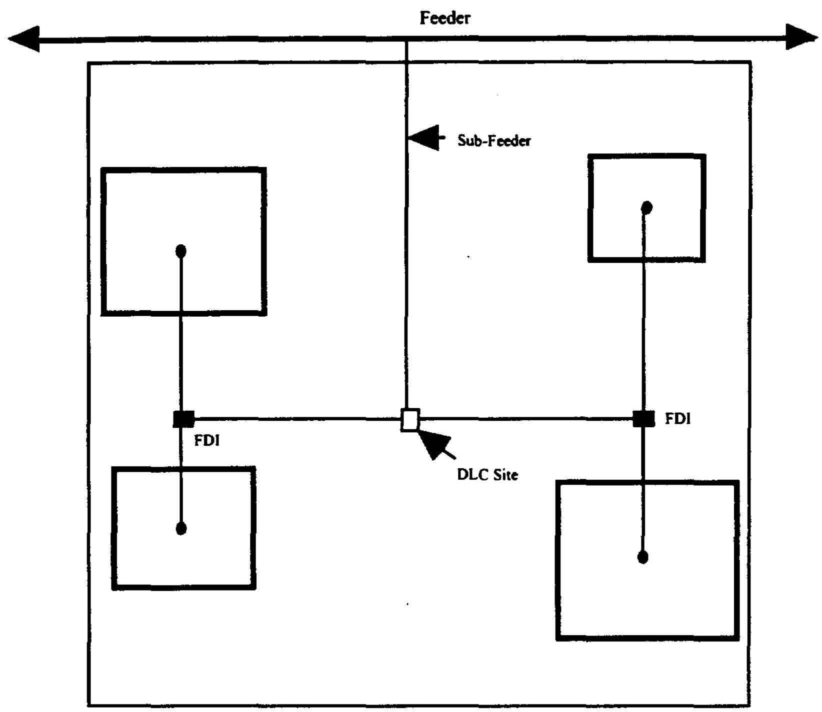
When the distribution cable sizing does not exceed 1,200 pairs, the Model allows for cost savings from placing fewer FDIs. More precisely, for ultimate grids that are served by distribution cables totaling less than 600 pairs, the algorithm essentially computes the cost of placing a single FDI within those ultimate grids. This is tantamount to co-locating the FDI with the DLC. In such cases, horizontal and vertical connecting cable is placed from the ultimate grid road centroid to the road centroid of a non-empty quadrant's road-reduced area. This condition is shown in Figure 6.4.

**Figure 6.4**
OUTSIDE PLANT DISTRIBUTION
FDI Co-Located with DLC
(Total Lines < 600)



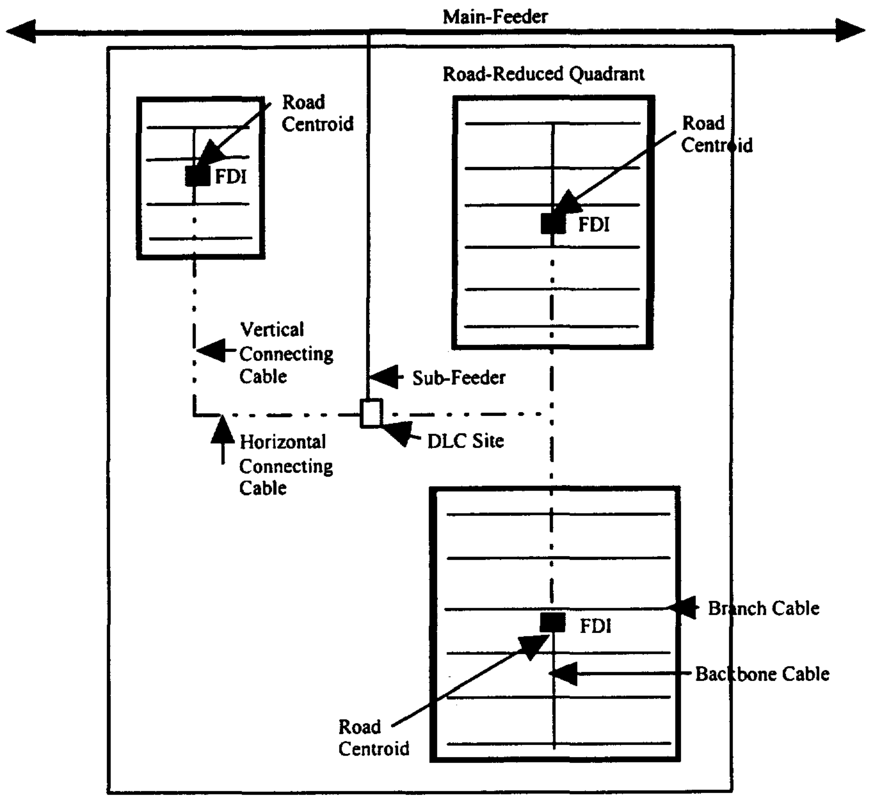

For ultimate grids containing line demand between 600 and 1,200 lines, the algorithm essentially computes the cost of placing two FDIs within those ultimate grids. This is tantamount to the two distribution quadrants located to the right of the DLC site sharing an FDI and the two distribution quadrants to the left of the DLC site sharing an FDI. Horizontal connecting cable connects the DLC to the FDIs and vertical connecting cable links the FDIs to the road centroid of the distribution quadrant. An example of this is displayed on Figure 6.5.

**Figure 6.5**
OUTSIDE PLANT DISTRIBUTION
FDI Shared by Quadrant to Right and Left of DLC
(Total Lines between 600 and 1200)




The backbone and branch cable distances are calculated using the area of the road-reduced area. While the cables might be placed in a different location, it is easy to think of a backbone cable as emanating up (north) and down (south) from the center of the road-reduced area. Branch cable is placed at 90 degree angles from the backbone cable to each terminal. (See Figure 6.6.) The final piece of distribution cable, the drop, extends from the branch cable to the middle of the customer's lot and is capped at 500 feet. Lot size within a distribution quadrant is based on the distribution quadrant's average lot size, determined by dividing the road-reduced area of the distribution quadrant by the number of locations, i.e. housing unit structures and business locations, within that distribution quadrant. Thus, lot size may vary across distribution quadrants within an ultimate grid.

**Figure 6.6**
OUTSIDE PLANT DISTRIBUTION




As a reasonableness check on cable requirements, the Model constrains the total length of cables (including the backbone, branch, vertical and horizontal connecting cables) within a distribution quadrant to not exceed the length of the road network in that distribution quadrant.

### 6.8 Distribution Equipment

Within the Model there are a number of rules that are used to select specific pieces of equipment to be used in the distribution plant. Among those rules with the most impact are:

- Within a grid, if the length of copper from the DLC to the last lot in a quadrant is less than 11,100 feet, 26 gauge cable is used to serve all customers. In those circumstances where the distance from the DLC to the last lot is greater than 11,100 feet, 24 gauge wire is used in all cables to and within the distribution quadrant. Where distances exceed 13,600 feet, extended range plug-ins are installed on lines that exceed 13,600 feet.

- The mix of aerial, buried and underground facilities is determined by terrain[38] and density[39] specific to that grid.[40]
- Terminals
    - Exterior Drop terminals are provided at each point where drops connect to branch cables and are sized for the number of connecting drops.
    - Indoor building terminals are placed on each multi-tenant building and are sized for the number of lines terminated at that location.
    - Different NIDs are used for business and residence locations. One housing is included for each living unit or business location, in addition to one protector and one interface per drop pair terminated.
    - Terminal cost input tables include entries for separate components of the installation process.
- Cables are sized using the following basic rules:
    - Branch cables are sized to the number of pairs for housing units and business locations. (This calculation takes the number of housing units times pairs per housing unit and the greater of actual business pairs per location or business locations times pairs per location.)
    - Each backbone cable is sized to carry 1/2 of the branch cable pairs to the FDI.
    - Cables throughout the feeder system are sized based on the actual number of pairs used from the FDI back to the switch.[41]

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[38] The nature of the terrain, i.e. rocky, sandy, hilly etc. is taken from the State Soil Geography (STATSGO) data based produced by the United States Department of Agriculture, and is defined for each microgrid. In most cases, a single microgrid covers a single terrain type, In the case that more than one type of terrain is covered by a single microgrid, a weighted average of terrain types is captured for the microgrid. Since the slope is one aspect of terrain, changes in slope affect cable length and cost.

[39] The model defines nine density zones based on lines per square mile. In addition to plant mix, density also influences cable fills and placement costs.

[40] More precisely, look up tables are utilized that specify cable mix based on terrain and density.

[41] The number of pairs used is determined by adding the actual number of business pairs to the number of housing units multiplied by a factor that accounts for the number of second lines for each housing unit. The model provides a second line factor on a state level based on ARMIS and NECA data. The user can use the default number, input a different state number, or input individual numbers at the wire center level.

## 6.9 Distribution Cable Requirements

The Model default inputs assume two pairs for a resident unit and six pairs for a business unit. The number of cable pairs per resident and business unit is a user adjustable input. The Model uses the actual number of business lines if it exceeds the user adjustable line per business location (currently set at 6). Using this design criteria, cables are appropriately sized.

## 6.10 Loop Length Calculation and Special Considerations

To measure the distance of the loop length the Model adds the following elements:

- Linear distance of the feeder to the subfeeder;
- Linear distance of the subfeeder to the subfeeder part 2;
- Linear distance of the subfeeder part 2 to the DLC;
- Length of the vertical cable;
- Length of the horizontal cable;
- Half the length of the branch cable;
- Half the length of the backbone cable; and
- Length of the drop cable.

The Model provides the user with the option of establishing a cap on the maximum loop investment. The cap can be evaluated at a national or wire center level. For example, if the user sets a cap at $10,000, each loop whose investment potentially exceeds $10,000 is capped at $10,000. This cap is a user adjustable input. One reason for providing the option to use a cap on loop investment is to allow for the possibility that regulatory/public policy may limit the maximum investment level per line that universal service funds can support. A second reason for the cap is to allow for technological alternatives, such as a wireless technology, for providing basic service beyond some user specified investment threshold. The Model results are typically provided on both a capped and uncapped basis.

## 6.11 Terrain

U.S.G.S. and Soil Conservation Service data for four terrain characteristics that impact the structure and placement cost of telephone plant are included as inputs to BCPM 3.1 by CBG and assigned to an ultimate grid. These terrain variables include depth to water table, average slope of the ground, depth to bedrock, hardness of bedrock, and surface soil texture. Combinations of these characteristics determine one of four placement cost levels.

Placement Cost Levels (increasing placement difficulty)

- (Normal) Neither water table depth nor depth to bedrock is within placement depth for copper or fiber cable, *and* surface soil texture does not interfere with plowing.
- Either soft bedrock is within cable placement depth *or* surface soil texture interferes with plowing.
- Hard bedrock is within cable placement depth.
- Water table is within cable placement depth.

When both fiber cable and copper cable are placed together in an underground or buried installation, the fiber placement depth is used to determine the placement difficulty.

### 6.12 Additional Features in the Model

The Model recognizes conduit and pole structure that is shared with power and cable industries. Sharing of structure rules are located in user adjustable tables. These tables incorporate the flexibility that was introduced in BCPM 1.1. For those unfamiliar with that previous version, the structure sharing inputs allow the user to have greater control over where sharing really takes place. The user can set the amount of sharing on the type of activity incurred such as plowing, rocky plowing, and cable boring.

### 6.13 Data Input File

All of the work creating the grid system and the feeder route distances is done outside BCPM 3.1 model using a combination of Mapinfo and C+ software. At this point, the data input file is prepared summarizing information about the grid layout and main feeder, subfeeder and subfeeder part 2 design and distances. When the Model is run, the feeder plant is sized, tapered, and the cost determined. The Model then designs, builds, sizes, and assigns costs to the distribution plant.

# SECTION 7.0

# SWITCHING

## 7.1 Introduction

The BCPM—Switching Module (BCPM-SM) is designed to develop per line switching investments for Universal Service Fund (USF) applications and to provide the basis for UNE costs. The Model fully supports a forward-looking economic cost methodology, and reflects generally available digital switching technology.

The Module was specifically designed to meet the design goals of the FCC as stated in various Universal Service notices. The goals include:

- Separate identification of host, remote, and standalone switches and calculation of costs specific to each type;
- Acceptance of data such as switch classification, wire center traffic characteristics, and switch investments from multiple sources; and
- Sharing of costs between the host switch and its attendant remote switches to reflect properly the efficiencies of such arrangements.

BCPM-SM includes a number of capabilities to meet these directives. The Model:

- Uses separate cost equations for host, standalone, and remote switches. Allowances are made, to the extent feasible, for the input of user-defined switch equations;
- Provides global data inputs for those study areas where specific data are not available; (All data inputs are available for inspection and can be replaced by the user as desired.)
- Can accept switch investments from several sources; (These sources could be either the Model's internal switch equations, data provided from FCC data requests, or investment results from Audited LEC Switching Models (ALSMs))
- Analyzes input data files to determine whether switch capacity constraints have been exceeded for any wire center, and if so, places an additional switch in that wire center; and

- Determines the realistic portion of each switch attributable to basic telephone service, by means of a process that calculates specific investments for a set of functionally significant investment categories (e.g. the line port.)

### 7.2. BCPM 3.1 Enhancements

BCPM 3.1 introduces a number of major innovations to the switch cost approach used in BCPM 1.1. The most important changes include:

- The BCPM 1.1 switch curve made no distinction between host and remote switches. BCPM has separate switch models for host, remote, and standalone switches.

- Where BCPM 1.1 estimated a single total switch investment, BCPM 3.1 calculates switching investments for each of several switch functional investment categories, using a separate curve for each category. This allows BCPM 3.1 to accurately identify, for each central office, the portion of investment that supports universal service. In addition, the switch can be accurately partitioned into non-traffic sensitive (Line Port) and traffic sensitive investments. BCPM 1.1 provided a single input that allowed the user to specify the percent of the total switch investment that was local, or universal service.

- BCPM 1.1 switch curves estimated switch functional investments based only on the number of lines in the office. In contrast, BCPM 3.1 uses a variety of inputs including call rates, usage levels, and number of trunks, as well as the number of lines. BCPM 3.1 allows input of usage levels for universal service that can be independent of the usage inputs used to engineer the switch. Usage inputs can be distinguished by residence and business lines if desired. Many data items can be input on a state-specific and/or wire-center specific basis with a "fallback" feature that allows the Model to use the state-level inputs in those cases where wire-center inputs are not available.

- BCPM 1.1 was based upon a sample of switch investments that included DMS-100 and 5ESS switches. The single switch curve, however, made no distinction between the two switches. BCPM 3.1 is also based on the 5ESS and DMS-100 switches and in addition, allows the user to specify a switch vendor, if that information is available.

BCPM 3.1 also provides the user an additional switch curve that reflects the costs for smaller switches.

- The BCPM 1.1 model was developed using responses to a "Best of Breed" data request sent to the LECs. This data request asked for discounted unit investments produced by SCIS runs. The resulting model in essence produced an average discount level for the companies polled. BCPM 3.1 is based on a similar data set produced by the BCPM sponsor companies (BellSouth, Sprint, U S WEST). The sponsor companies provided non-discounted switch investments for use in the switch curve. The investments were produced with SCIS runs, except for the U S WEST investments, which were produced with the Switching Cost Model (SCM).

- BCPM 1.1 used a single means, the switch curve, for estimating wire center switch investments. BCPM 3.1 can use several sources of investments to determine USF costs: the switch regression curve, direct input from an ALSM, or total switch investments from any other source. BCPM 3.1 can partition the investments from other sources by functional investment category, producing accurate estimates of universal service investments by switch.

- BCPM 1.1 did not have an algorithm to limit switch sizes. BCPM 3.1 has the capability to scan the input table to determine whether the capacity constraints for any given wire center have been exceeded. If a wire center has more than a user-defined number of lines, the Model automatically inserts a new switch entity. This overcomes a limitation that caused simple switch curve models to create "switches" with unreasonably large amounts of lines or usage.

## 7.3 Switching Overview

The modern digital switch is in essence a specialized minicomputer. Like all computers, it has a central processor, interfaces to the outside world, and internal data channels which carry digital messages (in this case telephone calls) from one component to another. To understand the switch costing methodology presented in this document, it is important to first discuss the basic functions and components of a switch.

### 7.3.1 Switch Functions

Central Office Switches provide the connection between a subscriber's local loop (access line) and the outside world. Modern digital switches can handle voice, data, and video signals as they link telephones, fax machines, and computers together on the public switched network. The functions performed by switches for local service include:

- Line Termination, or local interconnection to an exchange circuit (local loop);
- Line Monitoring, to ensure that requests for service (off hook) are reliably served;
- Usage Call Processing, Routing, and Completion;
- Interconnection to all Telecom carriers;
- Billing and Maintenance; and
- Vertical Services and Features.

### 7.3.2. Rate Elements Supported by Switching

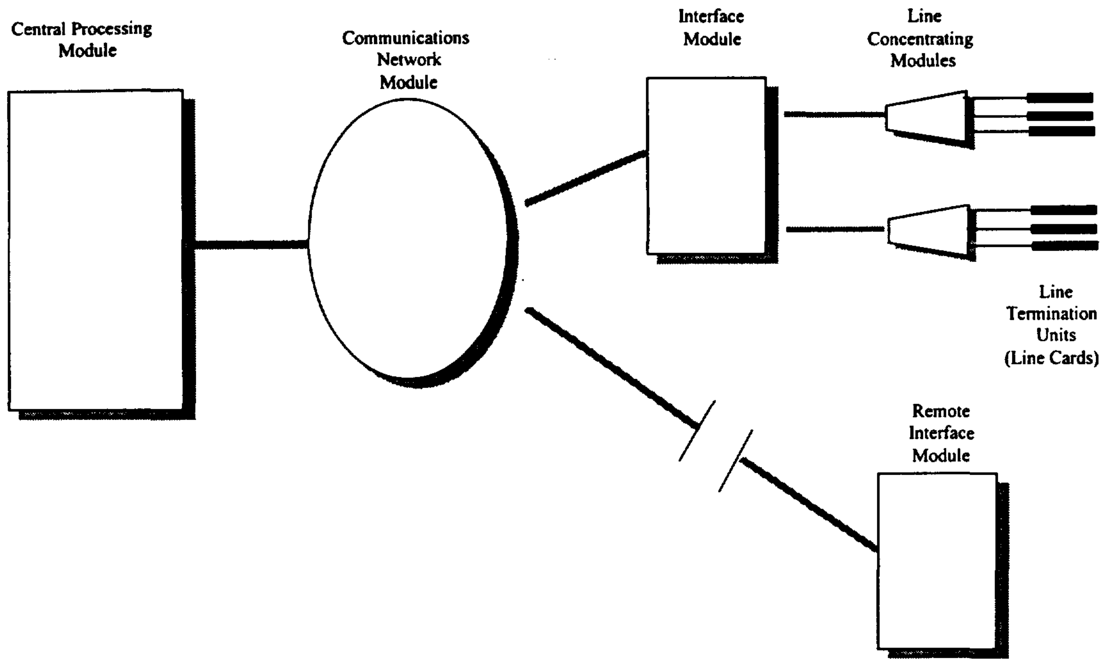
Some of the primary network cost and rate elements supported by central office switches include:

- Line Port,
- Line Usage,
- Trunk Usage,
- Local Tandem Switching (Part of Common Transport),
- Custom Calling, Centrex, and CLASS Features, and
- Signaling (Signaling System 7).

### 7.3.3. Switch Architecture

Modern digital switches are built in a modular fashion allowing any switch to be configured in a variety of different ways by combining standard components. This permits the switch to be designed efficiently and flexibly, and to grow as needed to support new subscribers and services. The same basic components can be used in different roles. For example, Line Termination Units and Line Concentrator Modules are used in host switches to terminate subscriber lines. When placed in a remote hut and connected to the host switch by umbilical trunks, these components can function as a remote "switch". In many cases, it may be more economical for the telephone company to place such a remote than to install Digital Loop Carrier equipment to serve the same subscribers.

Typical Switch Architecture




The architecture of a modern digital switch can be described generically as having three components: the Central Processing Module, the Communications Network Module, and Interface Modules. These three modules perform, respectively, central control, central call processing, and line termination/supervision. The two most common end office switches in deployment in the U.S. are the Lucent 5ESS® and the Nortel DMS-100®.

### 7.3.3.1 Interface Module (IM)

The Interface Module (IM), known as the Peripheral Module in the DMS-100® and the Switch Module(SM) in the 5ESS®, contains Line Termination Units or Line Cards, Line Concentrating Modules, and Digital and Analog Trunk interfaces. Line Termination Units provide the dedicated circuit termination between the customer and the network. Line Concentrating Modules bundle or funnel the individual circuits into speech links which connect to the Communication Module. Typically, the IM provides one speech link for every two to six line terminations. Trunk terminations, however, are not concentrated. The IM provides what are known in the industry as the basic BORSCHT functions of the switch:

- Battery,
- Overvoltage (protection from power surges),
- Ringing (power ringing),
- Supervision,
- Coding/Decoding (analog/digital conversion), and
- Hybrid Testing.

Many, but not all, IMs have limited internal call processing capability which allows them to connect calls which originate and terminate within the IM even in the event of a failure in the host switch. In particular, the 5ESS® has microprocessors located within the SMs which enable a large proportion of calls to be handled without the involvement of the central processing unit, or Administration Module. This is not necessarily a superior design feature, but it does have important implications in the development of a valid cost model.

#### 7.3.3.2 Communications Network Module

The Communications Network Module (CNM), also known as the Network Module (NM) in the DMS-100® or the Communications Module in the 5ESS®, is responsible for providing speech links between IMs. It is the core of the time-division-multiplexed switch fabric which efficiently connects and controls all of the major elements of the digital switch. The CNM also transmits the messages which pass between the CPM and IMs to coordinate call processing and administrative functions.

#### 7.3.3.3 Central Processing Module

The Central Processing Module (CPM) comprises the Administrative Module in the 5ESS®, and the Central Control Complex and Input/Output Controllers in the DMS-100®.

The CPM is responsible for the establishment and coordination of connections though the switch. It sets up internal connections between lines for intra-switch calls and between lines and trunks for inter-switch calls. It is the central collection point for billing and performance information and provides interfaces to the external billing and performance monitoring systems. The CPM provides the interface with the SS7 network. Maintenance and administrative functions, such as the establishment of customer service, are controlled here.

In general, the CPM of the DMS-100® is more involved in routine call processing than that of the 5ESS®. In the 5ESS®, most call processing is handled by distributed microprocessors located in the CNM and IMs.

## 7.4 Switch Model Methodology

### 7.4.1 Overview Of The Process

Although the process of determining per line switching costs for universal service entails numerous analytical steps, it can be summarized in three major phases.

- First, the Model compiles the switch-specific data inputs to be used for investment development.
- Second, BCPM generates total switch investments by functional category (FCAT) for each switch.
- Third, the Model uses these FCAT investments to generate a Busy Hour unit investment for each basic switch function, based on the subscriber calling and usage rates input into the Model.

Aggregating the costs associated with the requisite switch functions produces the switching investment per line required to provide basic service. For example, Universal Service requires a line port on the switch, usage of the central processing module, line and trunk CCS usage, and SS7 usage. BCPM determines for each of these investment categories what quantity of unit investment, by FCAT, is attributable to universal service. These investment "buckets" are then restated on a per-line basis for universal service.

The following outlines this three step process in greater detail.

### 7.4.2 Input Development Process

BCPM compiles its Common Language Location Identifier (CLLI)-specific inputs into a single input table that drives all of the investment and cost calculations. The index field that makes each row of data unique is the CLLI. The CLLI, Host CLLI for remotes, Rate Center, and number of working lines are always taken from the "area Raw File" also used by the Loop, Transport and Signaling modules. The switch type (5ESS or DMS), percent line fill, number of calls and CCS per residence and business line, and line to trunk ratio are taken from the User Data file where possible. The User Data file can include these data items for each CLLI. If the User Data file does not include any of these items for a given CLLI, then the Model populates the input table with the corresponding default data value from the State Defaults table.

BCPM allows the user to drive switch total investment calculations and Universal Service support calculations with user inputs for calls per line or usage per line. The Model can be optioned to use a single input parameter for calls per line and a single input parameter for CCS per line. These inputs are taken either from the CLLI-specific data file or state specific defaults. They are the values from which the switch is engineered, and which drive the ALSM investment calculations.

Alternatively, the user can provide assumptions or prescribed values for the number of calls per line (by residence and business) and minutes per call (residence and business). These inputs are provided from local and tolls calls. The Model can use these inputs to estimate total switch investments (using the switch curve) and to develop the Universal Service support investment amounts. It is recommended, however, that engineering inputs be used to estimate the total switch investment. This ensures that the Model produces total switch investments and unit investments that accurately reflect engineering judgment.

**Maximum Switch Size**--The user can define the maximum switch size by setting limits upon three switch parameters: Number of Lines, Total Busy Hour CCS, and Total Busy Hour Call Attempts. The algorithm determines values for each parameter using the public Input Data accessed by the Model. All three input parameters are based upon separate inputs for residence and business lines. If a wire center exceeds any one of the parameters, then the sub-routine may insert an additional switch or switches and evenly spread out the total line demand at the location among all assigned switches or remotes.

**Surrogate Switch Vendor Assignment**--If Switch Vendor / Type is included as part of the BCPM Data Input stream, then switches and remotes that do not match the two available options for switches (i.e., 5ESS®, DMS-100®) and remotes are assigned a proportion of each switch vendor type based on state-specific market shares specified by the user. For example, if a 50%/50% share is input as default, then the switch investment for those switches left undefined is a weighted average of 5ESS and DMS-100.

**Derived Inputs**--BCPM determines whether each switch is a host, remote, or standalone based on the CLLI and Host CLLI fields. If a switch has a Host CLLI, then it is tagged as a remote. If a switch has its CLLI designated as any other switch's host CLLI, then it is tagged as a host. Otherwise, it is tagged as a standalone.

The number of residence lines and business lines is obtained from the BCPM Loop module. Engineered lines are calculated from working lines and the percent fill. The number of trunks is calculated from the line/trunk ratio.

### 7.4.3 Switch Functional Investment Development Process

The objective of the first phase is to determine the total switch investment (in dollars) associated with each switch functional category, for each CLLI under study. Six switch functional categories have been identified: 1) Processor Related Cost; 2) Line Termination - MDF and Protector; 3) Line Port Cost; 4) Line CCS Usage; 5) Trunk CCS Usage; and 6) SS7. These functional categories are designed specifically to accommodate and be compatible with the extensive modeling work previously performed by companies such as U S WEST and Bellcore.

Functional investments can be developed via three distinct methods. The first method utilizes the BCPM Investment Development Process within BCPM. The second method develops functional investments with an Audited LEC Switching Model (ALSM) that can be input directly into the Model. The third method uses a total switch investment from any other source, such as regulatory reports filed by local exchange carriers. The third method separates the total investment dollars into functional categories based on category percentages developed within the Functional Investment Development Process. BCPM allows the user to incorporate a mixture of functional investments from all three sources within a model run. As a default, BCPM calculates its own functional investments for each CLLI being studied in the run. The user has the option of providing ALSM and/or other investments for each CLLI. Before the universal service investments are computed, the Model chooses the investment source to use for each individual CLLI.

#### 7.4.3.1 BCPM Method

The first approach, The BCPM Investment Development Process, is most appropriate to use when detailed specific switch by switch data is unavailable. The steps in the BCPM Investment Development Process are:

- Data Collection and Regression and
- Functional Investment Development.

The Data Collection and Regression process, which is performed outside of BCPM, results in a set of regression coefficients and equations that form "switch curves" for host, remote, and standalone switches. BCPM takes these switch curves as input and combines them with switch-specific data, such as the number of lines on each switch, to produce the Functional Investment by category for each switch.

##### 7.4.3.1.1 Data Collection and Regression Process (Switch Curve Development)

Initially, BCPM Sponsor Companies provided non-discounted total Functional investments for statistically valid samples of 5ESS® and DMS-100® switches, and their associated remotes, covering a reasonable range of switch sizes and remote sizes.[42] (The data provided includes vendor provided Engineering, Furnished, and Installation, EF&I.) The Sponsor Companies developed these investments by running ALSMs using detailed engineering data for the switches studied. This data includes the total switch investments for each of the Functional Investment categories outlined above.

Each Functional Investment sample is used as a dependent variable in a regression function. Regression analysis entails regressing total switch investment utilizing a set of multiple independent variables, e.g. number of lines, number of trunks, that explain changes in total switch investment. The regression coefficients indicate the dollar change in total switch investment for a one unit increase in the independent variable. For example, if the coefficient on number of lines is 175 this indicates that increasing the number of lines by one causes a $175 increase in total switch investment. Once these coefficients have been estimated, detailed data on these independent variables for specific serving wire centers enable the analyst to estimate the total switch cost associated with that serving wire center.

The dependent variables are regressed against the following independent variables:

- Standalone/Host / Remote Indicator;
- Number of Lines;
- Number of Trunks;
- Busy Hour Calls per Line;
- Busy Hour CCS per Line; and
- Switch / Remote Vendor / Type.

The ALSM runs also collect appropriate information on the switch (data that will be available in the BCPM public data sources) to allow further analysis of additional factors related to the cost of switching. These analyses are discussed in the Switch Cost Refinement section below.

This regression process results in a coefficient matrix of Switch Functional Investments by BCPM Input Data type (e.g., number of lines, CCS per line). This coefficient matrix is supplied as an input table to BCPM. The user can substitute other known relationships for the values in the coefficient matrix table. Caution is advised, however, as the investment results are highly sensitive to some of the coefficient values. The user should thoroughly understand regression analysis and the effect of each coefficient and constant in the table before attempting to substitute values.

#### 7.4.3.1.2 BCPM Investment Development

This process creates the default investment values for the functional investment categories.

Once the regression coefficient table has been developed from the step above, preliminary switch functional investments are developed. The BCPM Input Data values (either user-input or flows from other BCPM system modules) for each switch and remote CLLI for the study area are multiplied by their corresponding regression coefficients. Some of these BCPM input data values can be the same as those used to develop the regression coefficients, or can be state or national default values, as available. The detailed steps in developing the investments are:

**Calculate Total Investments and Bucket Dollars**--The total investment and each bucket investment are calculated by multiplying each category's coefficients by the corresponding switch specific data input. The Model selects the proper set of coefficients (standalone, host, or remote) base on the switch type derived in the input process. For example, a standalone switch investment might be $3m plus $350/line times the number of lines plus $550/trunk times the number of trunks. The Model differentiates between 5ESS and DMS-100 switches by making the switch type a dummy variable. If the switch is a 5ESS, for example, an additive or a credit may be applied to some of the coefficients.

If the switch vendor was left undefined in the user data table, then the Model uses switch market share for the dummy variable. For example, the 5ESS additive for the constant coefficient of the total investment equation might be -$1m. If the switch were undefined and the user had specified a 50% market share for 5ESS, then the additive would be -$1m * 50% or -$0.5m.

The exception to this coefficient process is the SS7 bucket, which is treated as a constant investment based on a global user input.

**Adjust Bucket Dollars**--The individual bucket estimations, when summed, produce a total investment that is slightly different from the direct total investment estimation. The individual buckets equations tend to be somewhat less precise than the total estimation. Therefore, it is necessary to adjust each bucket share to ensure that the individual buckets sum to the correct total. This is done by dividing the summed bucket total into the estimated total to create an adjustment factor. The adjustment factor is then applied to the individual buckets to bring them into alignment.

**Apply Discounts**--The final step in BCPM Investment Development is to apply the company-specific discount factors to these investments. The discount factors are based on vendor discount levels supplied to an input table by the model user. The discounts are multiplied by a set of Discount Adjustment Factors that are supplied with the Model to produce an effective discount level by FCAT. The effective discount level by FCAT varies because vendor discounts are applied to material items only. The ratio of material to vendor labor and installation varies by FCAT, hence the difference in effective discounts. The Discount Adjustment Factors are the result of a special study performed by BellSouth. This study compared the average effective discount level by FCAT to the non-discounted investments for a sample of central offices of various sizes. The Discount Adjustment Factors are specific to the switch vendor and type (host/standalone or remote).

#### 7.4.3.2 ALSM Method

The ALSM method can be implemented when detailed switching investment information is available for each specific switch. This is typically the case with larger LECs and is generally the output provided by their respective ALSMs. (This method may typically be used in state specific hearings dealing with UNEs). If this approach is used, the ALSM output is input directly into the Service Specific Investment Process through a special input table. BCPM combines the total switch investments from the ALSM output into the set of BCPM investment buckets. The ALSM investments input should be discounted using company-specific discounts in their development.

7.4.3.3 Small Switch Option

This option allows the model to access a switch curve specifically developed to reflect the costs for small host, standalone, or remote switches.[43] The user can specify thresholds for defining a "small" switch based on line sizes, or can use default values.

#### 7.4.3.4 Other Investment Method

[43] The Switch Curve used in this process was developed by Dr. David Gable of Queens College. It was presented to the FCC by Dr. Gable on August 20, 1997 in a study titled "Estimating the Costs of Switches and Cable Based on Publicly Available Data." The study was based on a regression analysis using data provided by the Rural Utility Service (RUS) for about 136 switches.

This method allows for the input of investments from sources other than BCPM or the ALSMs. A special table is provided for the input of a total switch investment. This investment, as with the others, should be vendor E,F,&I, and should be discounted. The user will need to identify the switch as host, remote, or standalone, and identify the vendor if possible. BCPM separates this total investment into functional investment categories using a percentage of investment by category developed in the BCPM Investment Process. An intermediate calculation in BCPM computes the average bucket shares for that area by Standalone, Host, and Remote switches.

#### 7.4.3.5 Switch Investment Refinement Process

This process selects the appropriate set of switch FCAT investments (BCPM, ALSM, or Other) to be used in the final service investment process. The result is a matrix of validated Total Switch Functional Investments by CLLI code and functional category. If FCC or other data have been supplied via the Other Investment Process, then that data will be selected for each CLLI. If such data have not been input for a CLLI, the Model looks to see whether ALSM data have been supplied, and if so, uses the ALSM data. If none of the alternative data sources has been supplied, the output from the BCPM Functional Investment Process passes through.

### 7.4.4 Service Specific Investment Development Process

The purpose of the Service Specific Investment Process is to calculate the per unit switching investments for universal service. The switching investments are later combined with other investments, for example transport and signaling investments, to produce a complete cost study for the service or rate element.

#### 7.4.4.1 Unitizing Process

This process breaks the Installed Total Switch Functional Investments down into Unit Switch Functional Investments for each CLLI code. First, the Model sets aside the portion of total FCAT investment that is not related to basic calling. For example, based on the Feature Loading Multiplier, the Model can define that 20% of the Processor Related category investment is related to features. That portion of investment would be excluded from the basis of the Processor Related unit investment. The unitizing is accomplished by dividing each of the total FCAT investments by the capacity constraint relevant to that category:

| **Functional Category** | **Divisor (Capacity Constraint)** |
|---|---|
| Processor Related | Number of Busy Hour Calls |
| Line Termination - MDF & Protector | Number of Lines |
| Line Termination - Line Port | Number of Lines |
| Line CCS | Number of Line CCS |
| Trunk CCS | Number of Local Trunk CCS |
| SS7 | Number of Basic Busy Hour Calls |

Each call local placed by a telephone subscriber requires either two or four end-office processor call setups, depending upon whether the call is intra-office or inter-office. If the call is intra-office, then originating and terminating call setups are required. Each inter-office call requires the originating/terminating setups, plus outgoing and incoming setups, for a total of four call setups. The number of Busy Hour Calls per Line is computed by adding the originating, terminating, outgoing, and incoming call setups for each line. Each type of call setup is considered one transaction or "call" for the purpose of this calculation. This number is derived by first computing a weighted number of BH local calls for residence and business. The weighted number of BH toll calls then is computed. The number of originating & terminating call attempts is the total of local and toll calls times two. The number of outgoing/incoming calls is determined by multiplying the local interoffice calls (computed from a default table input percentage) plus the toll calls times two.

The number of Line CCS is computed by multiplying the total residence CCS per line (local and toll) by the number of residence lines and the number of business CCS per line by the number of business lines. The total Trunk CCS is computed by multiplying the calculated number of trunks by the average CCS per trunk, a state default input. The results of the Utilizing Process is a matrix of Unit Functional Switch Investments by CLLI code and functional category.

### 7.4.4.2 Calculate Universal Service Portion of Investment by Switch

The next step is to determine the total investment attributable to universal service for each switch. This is done by multiplying the FCAT unit investments by the appropriate quantities, as shown:

| Functional Category | Multiplier |
|---|---|
| Processor Related Inv. Per Call | Number of Busy Hour Local Calls per Line (Res & Bus) * Number of Lines |
| Line Termination - MDF & Protector per Line | 1*Number of Lines |
| Line Termination - Line Port per Line | 1*Number of Lines |
| Line CCS Usage per CCS | Number of Busy Hour Local CCS per Line (Res & Bus) * Number of Lines |
| Trunk CCS Usage per CCS | Number of Local Trunk CCS per Line (Res & Bus) * Number of Lines |
| SS7 Inv. Per Outgoing Call | Number of Basic Busy Hour Outgoing Calls per Line (Res & Bus) * Number of Lines |

### 7.4.4.3 Calculate Unit Vendor Investment per Line by Switch

The Model calculates a universal service investment per line by taking the total USF investment from each FCAT and averaging it across either the switch, the rate center, or the host/remote complex, as appropriate. The purpose of this step is to accurately reflect the actual cost characteristics of each unique serving area, while at the same time ensuring that host resources are appropriately shared across each host/remote complex.

| Functional Category | Allocation Basis |
| --- | --- |
| Processor Related Inv. Per Line | Rate Center |
| Line Termination - MDF & Protector per Line | CLLI |
| Line Termination - Line Port per Line | CLLI |
| Line CCS Usage per Line | CLLI |
| Trunk CCS Usage per Line | Host/Remote Complex |
| SS7 Inv. Per Outgoing Line | Host/Remote Complex |

The processor investment per line is determined by a three-step process that allocates the host processor investment across all switches on the host/remote complex. The first step is to divide the total USF processor investment for all switches on the complex by the total number of lines on the complex. This produces a host processor investment per line. The second step is to divide the processor investment for each remote switch by its associated number of lines. This produces a remote processor investment for each remote. The final step is to compute the total processor investment per line for each switch. For standalone switches, this is simply the processor investment from step 1. For hosts and remotes in the same rate center, the per line investment is the weighted average of the host investment for the host and the host plus remote investments for each remote. This produces a single processor investment per line for all switches in the rate center. For remotes located outside the host rate center, the processor investment is the sum of the host processor investment per line and the remote processor investment per line.

The trunking and SS7 host office investments must be allocated by complex, since remotes are assumed not to have these facilities and use the trunking and signaling resources of the host. For each complex, BCPM divides the host USF trunking investment by the local trunk usage for all switches on the complex. SS7 investments are handled similarly.

#### 7.4.4.4 Installed Investment Process

The Switch Investment Refinement process results in a number that represents the material cost from the vendor for the switching equipment. To develop the total Installed (working) investment, investment loading factors must be applied to account for the additional activities and equipment necessary to install and support the switch. The factors applied are as follows:

- LEC In-Plant Factor - Telephone company labor and material needed to install the switch;
- Land and Building Factors - Central office floor space required by the switch;
- Power and Common Equipment Factors - Central office power plant equipment and miscellaneous equipment such as racks and bays needed to support the switch; and
- Sales Tax - In many states, sales tax is applicable to the material portion of the switch investment.

The output of this process is a matrix of Installed Unit Switch Functional Investments by CLLI code and functional category.